DRISI

CALTRANS DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION

TRANSFORMING IDEAS INTO SOLUTIONS

Research Notes

Geotechnical /Structures

May 2025

Project Title:

Analysis and Model Test of Buried Structures Crossing Highways under Seismic Loading

Task Number: 4037

Start Date: June 1, 2023

Completion Date: August 31, 2025

Task Manager:

Sharon Yen
Senior Transportation Engineer
Sharon.Yen@dot.ca.gov

DRISI provides solutions and knowledge that improves California's transportation system.

Analysis and Model Test of Buried Structures Crossing Highways under Seismic Loading

Development of seismic design criteria for buried structures crossing highway.

WHAT IS THE NEED?

Buried structures crossing highways (henceforth BSCH) – such as culverts, drainage structures, and fish and other wildlife passages – are important and ubiquitous assets of a transportation system, especially in rural areas. They either appear as inevitable components such as culverts, or as connection alternatives as, for example, tunnels. These types of structures typically require lower maintenance, and thus enhance the sustainability of a highway system. Yet, their seismic resilience is not fully characterized and accounted for.

Culverts and other buried structures in highway system are generally not designed for seismic loading and the current AASHTO LRFD Bridge Design Specifications basically provides no guidance in this area. But it is found that underground structures without seismic design provisions were damaged in the past earthquakes in many countries. Large, buried structures which are culverts but classified as bridges with bridge number assigned are needed more frequently nowadays than before, where seismic design should be considered. Therefore, the California Department of Transportation (Caltrans) needs to develop uniform design criteria for those large, buried structures crossing highways in design practice.

WHAT ARE WE DOING?

Analytical analysis for buried bottomless metal and concrete structures will be conducted in the research to investigate the soil-structure interaction under seismic loading. Typical earthquake records will be used to get the maximum responses. The results in the research will be compared with related research such as NCHRP 611 to verify the methods and provide possible future improvements. Structural behavior in longitudinal direction will be studied for flexural and shear design. The research finding will be implemented in developing and improving Structural Technical Policy and Bridge Design Manual for buried structures in the state highway system.

WHAT IS OUR GOAL?

The goal of the research is to develop seismic design criteria, methods, and analysis workflows for large span (for spans over 20 ft) buried structures such as the buried metal and reinforced concrete bridges. This effort will thus mitigate the risk of the damage for buried structures under earthquake and will increase the safety and serviceability of these structures. It will also remove the barrier to the application of (typically more than 20 ft) structures with large spans due to lack of seismic design criteria in California and thus provide an additional alternative to bridges in type selection to achieve more cost effective and low maintenance products.

WHAT IS THE BENEFIT?

The research work will improve the safety of the underground structures in the highway system under future earthquakes. Meanwhile, it helps to provide a low maintenance (because of no expansion joints and no exposed deck) and better seismic resistance structural type (buried structures usually are more resilient for seismic resistance) comparing with bridges. The application of the research results to Caltrans practice will meet objectives in the Structures Strategic Direction for Bridges.

WHAT IS THE PROGRESS TO DATE?

The project is contracted with University of California, Los Angeles (UCLA) and University of Reno, Nevada (UNR).

Various buried structure configurations and study parameters have been identified for analytical work. Numerical models are being developed to investigate the soil-structure interaction (SSI) of the structure under seismic loading.

Selection of seven suites of ground motions ensuring that the chosen ground motions are representative of the seismic conditions relevant to the arch structures under investigation. These ground motions are selected to cover a broad range of magnitudes, distances, and site conditions, providing a comprehensive basis for the seismic analysis. The selection process involves carefully matching the spectral characteristics of the ground motions to the design response spectrum, which allows us to capture the variability in seismic demand and ensures the robustness of our simulation results.

The RC arch structures are modeled with varying geometric and material parameters to evaluate the influence of these factors on seismic performance. The structures are embedded within the soil domain, with contact conditions carefully defined to simulate the interaction between the soil and the structure. These parameters include the arch curvature, thickness, material properties, and boundary conditions, which are systematically varied to assess their impact on the seismic response.

IMAGES

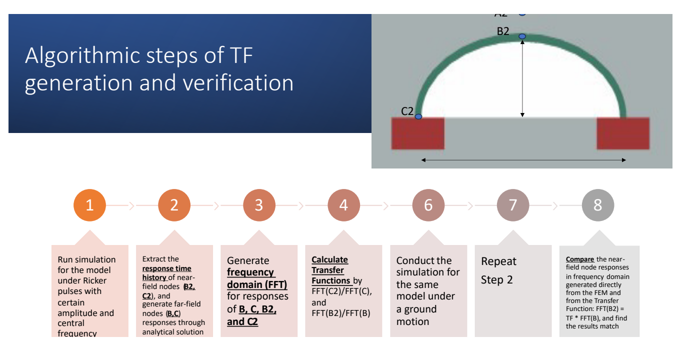

Image 1: Study methodology and transfer function development (curtesy of UCLA/UNR).